

Learning by Doing: The Potential for Experiential Education in Engineering Physical Chemistry

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Abstract— *Background: Experiential learning, characterized by hands-on engagement and active knowledge construction, has gained prominence in science and engineering education. This shift is in response to the limitations of conventional teaching methods, which often emphasize passive learning and fail to connect complex and theoretical classroom knowledge with practical applications. Purpose: Engineering Physical chemistry (PChem) students often have negative perceptions and low expectations for success in PChem, attitudes that likely affect their performance. Students mostly struggle in understanding the fundamental theoretical concepts and their application in solving complex numerical problems in PChem during their first year in undergraduate programme. To help students in learning to solve the problems related to PChem course, experiential learning classroom modules was implemented for small number of PChem students (CEB1023/CFB1023). Methodology/Approach: To bridge the gap between theory and practice, a student-centered approach via industrial visit, gas hydrate laboratory, adjunct lectures and case studies related to physical chemistry course were implemented for medium to large number of Physical Chemistry students (CEB1023/CFB1023) in chemical engineering program. Students were divided into number of group according to experiential approach. Percentile method has been used to analysis the obtained data. Findings/Conclusions: Data were analyzed through a qualitative-descriptive approach. Students' experiential learning influenced their personal and programmatic views of prevention training. Implications: The benefits of experiential learning in prevention will enhance students' education and future employment experiences. Future studies should improve upon training delivery and examine the acceptability of this method of delivery in the rural population.*

Keywords— *Physical chemistry, experiential learning, field trips, learning outcomes, lab visit.*

I. INTRODUCTION

In general, education is one measure of the progress of a country. Developed countries are characterized by their level of education and the ability of their people to keep up with developments in science and technology. Institutions as a place of education for the community plays an important role in supporting the progress of the country. At institutes, people can learn many things, such as acquiring and improving their skills[1]

Chemical science learning is currently very important, meaning that learning success must be increased in the learning process. One possible effort is learning that can involve students through direct experience to improve students' current skills. The learning model that allows students to be directly and actively involved in making experience the basis for acquiring knowledge is the experiential learning model. Experiential learning is a learning model that uses experience as a learning tool, examines experience,

concludes and changes experience through direct experiments.

One of the efforts in the field of education is to make various efforts to improve learning in institution. Among the efforts made are carrying out learning using various innovative learning models [4].

Kolb's Experiential Learning model explains that concrete experience, reflective observation, abstract conceptualization and active experimentation form a four-stage process (or cycle) transformed into effective learning. [5]

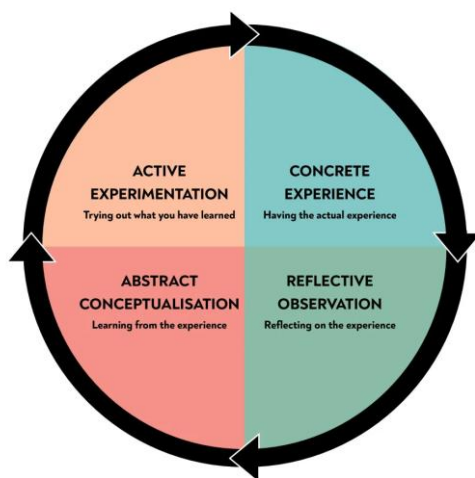


Fig.1: Experiential Learning Cycle

Kolb's model draws heavily on the progressive educational philosophies of John Dewey and the developmental theories of Jean Piaget, who both emphasized the pivotal role of active engagement in learning.

From Kolb's perspective, knowledge emerges through a cyclical interplay between "doing" and "thinking," which is why he frames learning as "the transformation of experience" rather than simply the absorption of facts [6-7]. Each stage presents a unique lens through which experiences evolve into insights and skills.

Critically, Concrete Experience (CE) anchors learners in hands-on action or tangible participation, setting the stage for deeper reflection. Reflective Observation (RO) then prompts individuals to examine what happened and how it aligns – or conflicts – with their existing understanding of the world. Out of this comparison arises Abstract Conceptualization (AC): a moment of building or refining mental models and theories that help make sense of new experiences. Finally, Active

Experimentation (AE) puts these theories to the test in a real or simulated environment, allowing learners to adapt their concepts, generate fresh questions, or move seamlessly back to another cycle of new experiences.

In science education, this model encourages hands-on activities, allowing students to apply scientific concepts, reflect on their actions, form new theories through logical analysis, and then test these theories through further experimentation, leading to deeper understanding and skill development. In engineering chemistry education, experiential methods like experiments and simulations motivate student interest, enhance concept comprehension, and build critical thinking abilities.

Physical Engineering Chemistry is one of the required main courses in Chemical Engineering programme. It is important for Chemical engineering students to pass and to understand the contents of PChem course as this course is a pre-requisite of chemical engineering thermodynamics, Reaction engineering and separation process for Chemical Engineering Program in UTP. Based on the feedback from the students taking Chemical Engineering, the students attributed difficulties associated with the course to superficial conceptual understanding and its application in solving complex numerical problem and plus having no motivation or interest in the topic. From lecturer observation and literature, for example, students had difficulties with conceptual understanding of ideal gas law concept and how to drive the ideal gas equation and further limited understanding on application of ideal gas equation in complex problems in PChem. This problem basically comes from limited understanding of what basic rules of Calculus, Algebra and Psychometric issues such as reliable assessments and addressing correlations with other factors. Students with conceptual understanding know more than isolated facts and methods.

PChem students often have negative perceptions and low expectations for success in this course. Students mostly struggle in understanding the fundamental theoretical concepts and their application in solving complex numerical problems in PChem during their first year. To help students in learning to solve the problems related to this course, Experiential learning was implemented for 184 students (CEB1023/CFB1023).

A contemporary approach to the teaching-learning process would start with experiential learning (EL), sometimes known as learning by doing. To assist

students apply their knowledge in real-world situations, the National Education Policy (NEP) places a greater focus on experiential learning. This paper focuses on how EL uses practical laboratory experiments based on design and development, professional skill (PS), field trips, project-based learning (PBL), and multidisciplinary projects to enhance engineering students' academic performance and overall development with worldwide acceptance[8-9]. Physical Chemistry course is one of the core disciplines in Chemical Engineering offered by Department of Chemical Engineering at Universiti Teknologi PETRONAS (UTP). A typical class of this course at UTP consists of approximately 150-200 students. Based on the experience of the lecturers teaching this course, most students faced some misconceptions and difficulties in the area of conceptual understanding and formula application; and thus they lacked ability to solve complex numerical problem especially at higher order level of knowledge (K4 apply, K5 evaluate and K6 create). Students found that mathematical derivations and their formula applications are the toughest area in in this course.

II. EXPERIENTIAL LEARNING

The method of learning via experience, action, or "learning by doing" is known as experiential learning (EL). It uses a learner-centered educational approach and encourages successful and active learning both inside and outside of the classroom. Deeper comprehension, improved memory retention, and the acquisition of critical life skills are all facilitated by EL. A constant cycle of experience, introspection, conceptualization, and experimenting leads to proficiency. According to Antonio and Albort-Morant [10] experiential learning is an active learning process where students actively create knowledge by doing tasks and thinking back on their experiences.

In order to make education more experiential, comprehensive, integrated, inquiry-driven, discovery-oriented, learner-centered, discussion-based, flexible, and pleasurable, pedagogy must change, according to the National Education Policy (NEP). Experiential learning is advised at all educational levels in accordance with NEP recommendations [11-12]. A variety of activities, such as practical laboratory experiments, internships, workshops, seminars, project-based learning (PBL), activity-based learning (ABL), bridge courses, technology-based learning (TBL), research-based learning (RBL), real-field

practices, program-specific research (PSR) activities, multidisciplinary projects, professional skill development, and employability skill development initiatives, can be used to implement EL.

The experiential learning approach offers several significant benefits, including:

- Enhancing students' ability to adapt effectively to new and unfamiliar situations.
- Bridging the gap between theoretical concepts and practical applications.
- Enabling more authentic and accurate assessment of students' skills and competencies.
- Facilitating deeper conceptual understanding of the subject matter.
- Strengthening students' capacity for creative, critical, and out-of-the-box thinking, as well as the application of knowledge to real-world problem solving.
- Fostering lifelong learning skills, including the ability to learn continuously in professional and workplace settings.
- Improving decision-making and problem-solving abilities.
- Promoting interdisciplinary learning, social awareness, career readiness, cultural development, leadership, collaboration, and the development of essential professional and intellectual

2.1 Course Context and Participants

The study was conducted in an undergraduate Engineering Physical Chemistry course offered to second-year engineering students. A total of 186 students were enrolled in the course during the study period. The course traditionally follows a lecture-based approach covering core topics such as thermodynamics, chemical kinetics, electrochemistry, and surface chemistry. To enhance conceptual understanding and practical relevance, experiential learning (EL) strategies were systematically integrated into the course delivery alongside conventional lectures.

2.2 Experiential Learning Interventions

The EL framework adopted in this study emphasized *learning by doing* and *learning through real-world exposure*. The following interventions were implemented throughout the semester:

Field Visits: Students participated in guided visits to relevant industrial organizations like The Camfil group, and research laboratories of Gas hydrate group, enabling them to observe real-world applications of physical chemistry principles. Program providers frequently collaborate closely with schools, offering supplementary materials that prepare students in advance and support reflection, conceptual understanding, and active experimentation after the field trip.

Adjunct/Guest Lectures: Industry professionals from various organizations like PETRONAS, and researchers delivered lectures connecting theoretical concepts to engineering practice, current technologies, and industrial challenges. Guest lectures expose students to real-world applications and expert perspectives beyond the syllabus. By interacting with professionals from diverse fields, students better connect theory with practice, gain career inspiration, and engage in dynamic, memorable learning experiences by expanding horizons beyond classroom.

Laboratory Visits: Structured lab visits were organized to expose students to advanced instrumentation and experimental techniques related to physical chemistry.

Poster Presentations: Students worked in small groups to prepare and present posters on selected topics, promoting peer learning, literature review skills, and scientific communication.

Motivational and Career-Oriented Talks: Sessions were conducted to highlight the relevance of physical chemistry in engineering careers, research, and higher studies, aiming to improve student motivation and engagement. By introducing individuals to diverse industries and career pathways, these discussions help them identify their interests, clarify career goals, and understand the skills needed for specific professions, thereby informing their academic decisions and future career planning.

These activities were aligned with specific course outcomes to ensure coherence between experiential components and academic objectives.

2.3 Data Collection

To evaluate the effectiveness of the experiential learning approach, both quantitative and qualitative data were collected:

Student Feedback Survey: A structured questionnaire was administered at the end of the course to capture students' perceptions of learning effectiveness,

engagement, motivation, and relevance to real-world engineering problems.

Academic Performance: Student performance was analysed using internal assessment scores and end-semester final examination results by implementing experiential learning and compared with previous semester results without using experiential learning.

Classroom Observations: Instructor observations were recorded to assess student participation, interaction, and enthusiasm during EL activities.

2.4 Data Analysis

Survey responses were analysed using descriptive statistics to determine trends in student perceptions. Performance data were compared with previous cohorts taught using traditional method of teaching to identify improvements in learning outcomes. Qualitative feedback was thematically analyzed to extract recurring patterns related to student learning experiences.

III. RESULTS AND DISCUSSION

3.1 Student Perception of Experiential Learning

Analysis of the survey responses in a class strength of 168 revealed that most students (>80%) reported positive learning outcomes from the EL interventions. Students indicated that EL activities helped them to develop a better conceptual understanding of abstract physical chemistry topics. Relate theoretical principles to practical engineering applications. Improve engagement and interest in the subject. Further gain exposure to industrial practices and professional expectations. Poster presentations and laboratory visits were particularly well received, with students highlighting improved confidence in explaining scientific concepts and enhanced teamwork skills.

3.2 Impact on Academic Performance

Comparison of assessment results shown in Fig 2 & 3 showed a notable improvement in overall academic performance compared to previous offerings of the course delivered predominantly through traditional lectures. It is observed that approximately 37.5% and 32.7 % of students were able to get A+ grade in final exam and internal assessment using experiential learning. Students demonstrated improved problem-solving ability and conceptual clarity, especially in topics linked directly to experiential activities such as kinetics, electrochemistry, and thermodynamics. Overall the grades of students have improved and there

is less than 10% percentage of students who are below C+ grade. Considering the complete experiential learning cycle, both during and beyond the visit, can improve learning outcomes in interpretive and educational programs. For school field trips or group visits, this may require closer collaboration between interpreters, teachers, and chaperones before and after the visit to ensure the full experiential learning cycle is achieved. And this behaviour is clearly observed by the students' performance without implementing experiential learning they were able to achieve grades till F and most of the students were in the range B+ to C- grade during September 2024 session as shown in Fig 3. By implementing experiential learning there has been a phenomenal performance growth of grades of students and as well as their problem-solving capability and conceptual thinking abilities improved. The suggested future research approach will be of interest to educators, academics, and researchers.

3.3 Student Engagement and Motivation

Instructor observations and qualitative feedback suggested increased classroom participation, higher attendance during EL-integrated sessions, and improved student-faculty interaction. Motivational talks and adjunct lectures played a key role in helping students appreciate the relevance of physical chemistry to engineering practice and career pathways.

3.4 Overall Effectiveness of Experiential Education

Out of the 186 students enrolled, the maximum proportion of students benefited from the experiential learning approach, as evidenced by positive feedback, improved performance, and enhanced engagement. While a small fraction of students initially expressed discomfort due to unfamiliarity with non-traditional learning methods, most adapted quickly and acknowledged the value of the approach by the end of the course.

These findings reinforce the potential of experiential education as an effective pedagogical strategy for Engineering Physical Chemistry, supporting deeper learning and better preparation for professional practice.

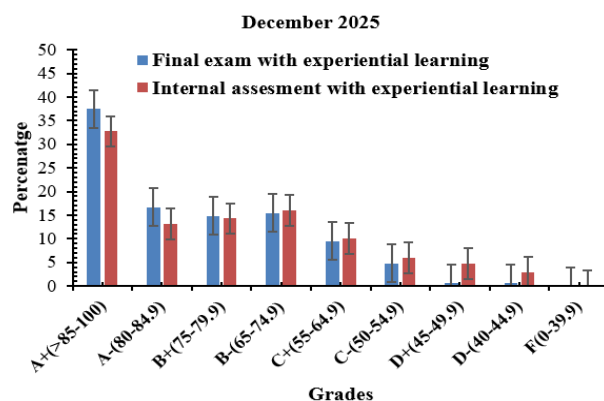


Fig.2: Percentage attainment by implementing experiential learning in December 2025

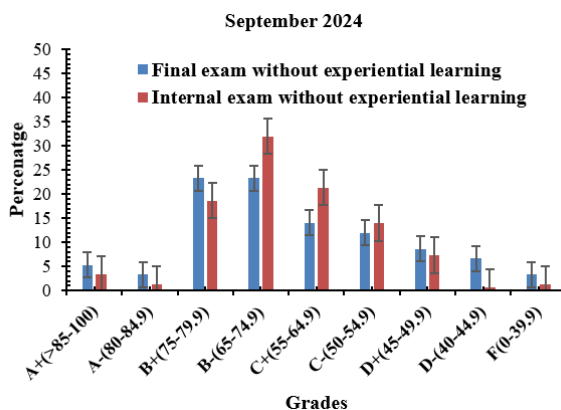


Fig.3: Percentage attainment without implementing experiential learning in September 2024

IV. CONCLUSION

This research focuses on the importance of experiential learning in improving engineering education, especially for first-year engineering students in PChem coursework. The experiential education approach successfully engaged the vast majority of students (>70%) and produced measurable improvements in both academic performance and student satisfaction, demonstrating strong potential for broader implementation in STEM education. It significantly enhances students' practical understanding, boosts learning motivation, sharpens awareness of the skills required for post-graduation employment, and supports the development of professional networks for career growth. This work offers learning outcomes, teaching methods, and curriculum design implementation using authentic experiential learning, which presents an innovative teaching model that fosters higher order thinking skills. To further enhance teaching and learning experiences that promote higher order thinking skills future research may explore collaborations with local

NGOs to facilitate knowledge exchange and the sharing of relevant insights.

REFERENCES

- [1] Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary educational psychology*, 36(1), 4-12.
- [2] Dabamona, S. A., & Cater, C. (2018). Understanding students' learning experience on a cultural school trip: Findings from Eastern Indonesia. *Journal of Teaching in Travel & Tourism*, 1-18. [htt](#)
- [3] Georgios Tsaparlis (2016), The logical and psychological structure of physical chemistry and its relevance to graduate students' opinions about the difficulties of the major areas of the subject, *Chem. Educ. Res. Pract.*, 17, 320-336.
- [4] Walangadi, H., & Umar, E. (2021). Application of Innovative Media and Learning Models Pandemic TIME Covid-19. *JournalNX*, 7(06), 118-122.
- [5] Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education, Inc.
- [6] Nallakukkala, S., & Lal, B. (2023, November). Developing Complex Problem-Solving Skills Among Physical Chemistry Students by Implementing Flipped Classroom Module. In *International Conference on Advancing and Redesigning Education* (pp. 455-460). Singapore: Springer Nature Singapore.
- [7] Dale, R. G., Powell, R. B., Stern, M. J., & Garst, B. (2020). Influence of the natural setting on environmental education outcomes. *Environmental Education Research*, 26(5), 613-631. <https://doi.org/10.1080/13504622.2020.1738346>.
- [8] Lee, H., Stern, M. J., & Powell, R. B. (2020). Assessing the influence of preparation and followup on student outcomes associated with environmental education field trips. *Environmental Education Research*, 26(7), 989-1007. <https://doi.org/10.1080/13504622.2020.1765991>.
- [9] Powell, R. B. (2016). Methods development for systematic investigation of factors driving outcomes in informal STEM environmental education programs. *NSF Award Number 1612416. Directorate for STEM Education*, 16(1612416), 12416..
- [10] Albort-Morant, G., Leal-Rodríguez, A. L., Fernández-Rodríguez, V., & Ariza-Montes, A. (2018). Assessing the origins, evolution and prospects of the literature on dynamic capabilities: A bibliometric analysis. *European Research on Management and Business Economics*, 24(1), 42-52.
- [11] Labib, W., & Abdelsattar, A. (2025). Examining the Impact of Construction Field Trips on Learning Outcomes: Perspectives from Structural Architecture Courses. *Education Sciences*, 15(5), 562.
- [12] Nallakukkala, S., & Panda, S. (2021). Effect of Self-study component towards Students Performance in Chemical Engineering Coursework: Case Study of Chemical Engineering. *Journal of Engineering Education Transformations*, 34(3), 114-126.